The New Data Acquisition System of the First Telescope in HEGRA

J. Cortina[1], J.A. Barrio[2] and G. Rauterberg[3]
for the HEGRA collaboration

[1] *Max-Planck Institut für Physik, Föhringer Ring 6, 80805 München, Germany.*
[2] *Facultad de Ciencias Físicas. Universidad Complutense 28040 Madrid, Spain.*
[3] *Institut für Kernphysik, Universität Kiel, 24118 Kiel, Germany.*

Abstract. The first imaging Cherenkov telescope of the HEGRA collaboration (CT1) detects VHE gamma rays in stand-alone mode. Last year CT1 was equipped with new high-reflectivity mirrors and a next-neighbour trigger which have enabled reduction of the energy threshold to around 700 GeV. In addition completely new software for the data acquisition has been developed and installed in the past months. Here we report on the features of the new system and some of the tests which have been performed with it.

INTRODUCTION

CT1 is the first Cherenkov telescope of the HEGRA collaboration. It is located at the HEGRA site on the Canary island of La Palma and is equipped with a camera consisting of 127 0.25° diameter pixels. It has an equatorial mount and works in stand-alone mode with an energy threshold around 700 GeV. In the past two years CT1 has undergone a number of improvements in both its hardware and its software.

On the hardware side we have replaced the old mirrors with new ones provided with higher reflectivity and added a new ring of mirrors to the telescope disk. A new next-neighbour trigger has been installed which has allowed us to lower the accidental trigger rate and further decrease the energy threshold.

On the software side the old Macintosh-based data acquisition system has been upgraded to a state of the art PC-based DAQ running under Linux.

HARDWARE IMPROVEMENTS

CT1 was originally equipped with 18 round glass mirrors making up a total reflective area of 5 m^2. The resistance of the stand prevented any further increase in the mirror area using new glass mirrors. We found a way to overcome this

limitation by using some newly developed diamond-turned light-weight aluminium mirrors [1,2].

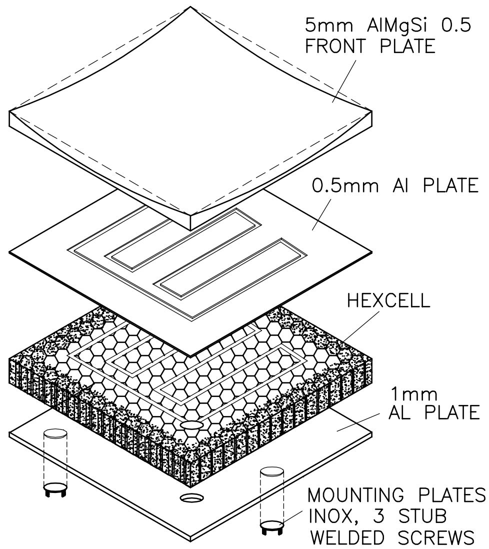

FIGURE 1. An exploded view of the aluminium mirror inner structure. The actual mirrors in CT1 are of hexagonal shape.

Figure 1. shows an exploded view of one of the mirrors. It is are made up of a HEXCELL Al core, sandwiched between the reflecting Al front plate and an Al backplate. A resistive heating wire is integrated in order to prevent dew formation or ice deposit on the surface (the usefulness of the new heating was demonstrated already on the following winter on days of high humidity and intense icing which even managed to bend down some of the old mounts). The reflective surface is generated by diamond turning. A wet-formed anodic Al_2O_3 layer of 120 nm thickness protects the delicate aluminium surface. They were built with a hexagonal shape in order to optimally cover the disk. Each mirror weights 6 kg, has an area of 0.31 m^2, a mean reflectivity of 83-85% between 300 and 500 nm and focal point spread of 2 arc minutes. Figure 2 shows the spectral reflectivity after anodization. The light weight of the new mirror allowed us to add another ring of mirrors to the original disk. All in all the reflecting area doubled to a total of 10 m^2.

The old trigger was based on simple majority of any 2 out of 127 pixels within a 13 ns time window. Due to the night sky noise and large signals from ion feedback [4], the individual trigger threshold had to be set to the equivalent of 15 pe's in order to keep the accidental trigger low. We replaced this trigger for a next-neighbour logic one [5] which enables us to reduce the single pixel threshold to 12 pe's. This

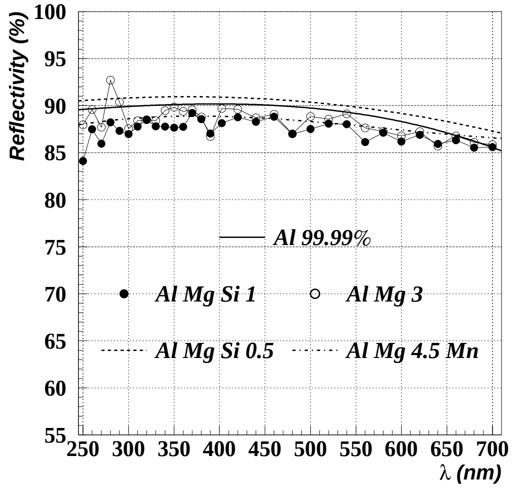

FIGURE 2. Spectral reflectivities for different alloys and surface protection materials. Al Mg 4.5 Mn is the alloy adopted for CT1.

in turn brings the trigger rate from 15 Hz (mostly accidental triggers) down to 3 Hz.

The enhanced mirror area along with the higher sensitivity results in a γ energy threshold reduction from 1.5 TeV to around 700 GeV. In winter 1998 we measured the Crab Nebula with a significance of 3.7 $\sigma/\sqrt{t}$ and a rate of 27 $\gamma/hour$. The time necessary for a 6 σ flux detection has been reduced from 76.1 hours to less than 4 hours [3].

SOFTWARE IMPROVEMENTS

The camera of CT1 consists of 127 EMI-9083A photomultipliers. The signals of these PMTs are directed to a central station where they are processed using CAMAC and NIM electronics: the charge is digitized in a 10 ns window using Le Croy 2249A ADCs; the next-neighbour trigger is implemented as a NIM module; and a number of other modules allow to monitor ADC currents, single trigger rates and general status of the telescope. The CAMAC electronic modules were in turn accessed by a Macintosh computer through two special crate controllers [6]. The system was slow, difficult to upgrade and had run into a good number of limitations. We decided to exchange it for a new concept based on a PC running under Linux.

Two new Wiener CC16 crate controllers were installed which are interfaced to a 300 MHz Pentium II using PC16-Turbo ISA cards. The PC runs under Linux 2.0.36. Linux is not a real-time operating system. Thus in order to minimize the deadtime imposed by the normal telescope operation we had to split the data acquisition system in a fast event builder and a slow user interface.

A new driver was developed for the CAMAC interface cards allowing very fast interrupt-driven acquisition of the pixel data. The dead time is well below 0.5%

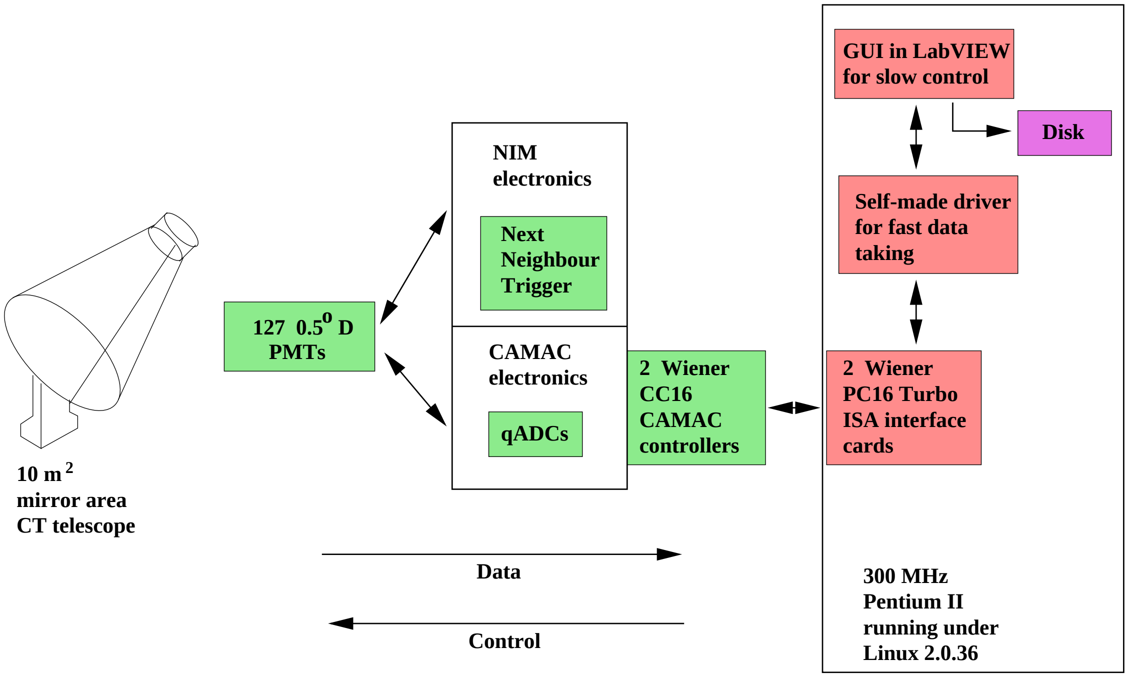

FIGURE 3. Diagram of the new data acquisition system.

and the system has proven to work in a stable way up to rates in the order of 50 Hz (more than 10 times our current data taking rate). The driver itself acts as an event builder acquiring events at interrupt time with less than 10 μs latency time and piping them to a slower control program through a memory FIFO. An overview of the system is displayed on figure 3.

The telescope control and interface to the user are realized in a program written in National Instruments LabVIEW programming language. LabVIEW is provided with multithreading capabilities which fit very well the requirements of our system and an easy to program graphical interface eviroment. The interface (see figure 4) enables the telescope operator to fully manage the different telescope functionalities and data taking. It saves telescope events and control data to hard disk. With respect to the old system the tracking has been optimized for an equatorial mount telescope. New features of the system include online run booking; full access to data, run books and program documentation via www; an interface to the xephem catalogues (90,000 sources) and, in the near future, online data analysis, an interface to a weather station and an autonomous GPS unit, a CCD-based sky transparency monitor and an autoguiding system.

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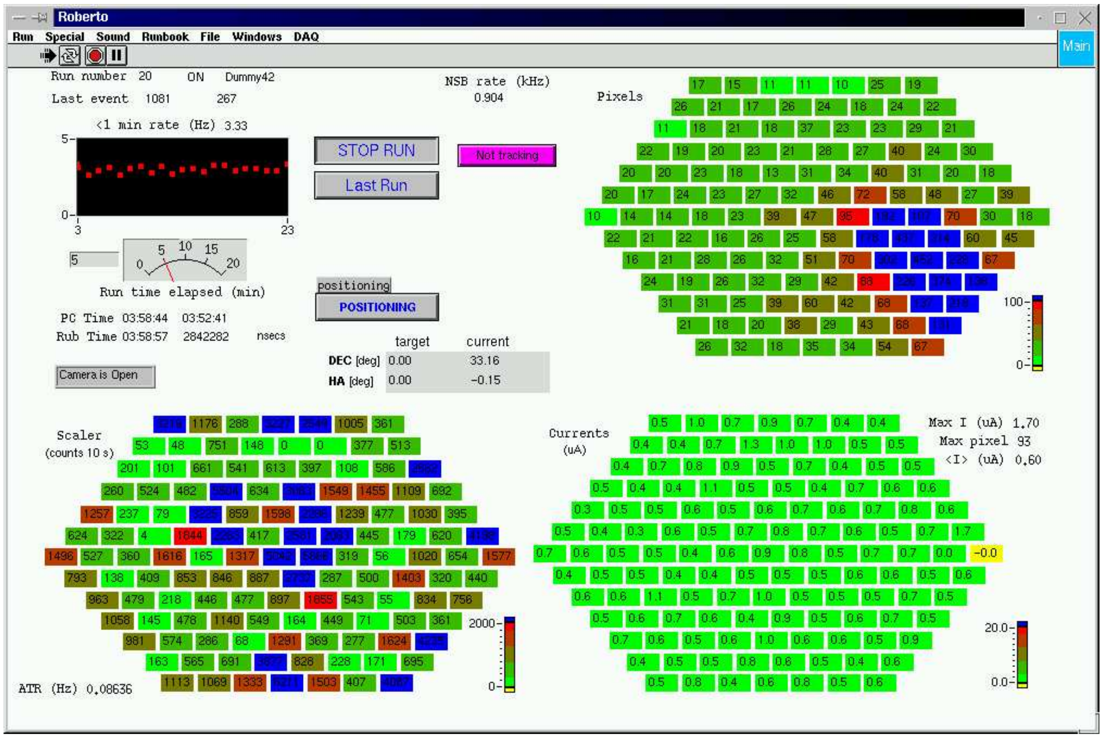

FIGURE 4. The Graphical User Interface allows easy monitoring of the telescope status and steering of its functionalities. This image is a snapshot of a real event, showing the values of the pixel ADCs for the event along with average currents, single pixel trigger rates and other telescope status information.

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